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Beyond waste elimination: Assessing lean practices in product development

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Abstract

Maintaining simultaneous focus on efficiency and effectiveness is a difficult yet necessary strategy to deliver commercially viable products in today's global world of competition. As a result, manufacturing companies aim to shift from a *modus of operandi* dominated by removing waste at the factory floor to leveraging value creation in all direct or indirect activities within the product value stream. One of the most popular strategies in this regard is to apply the Lean concept in product development (PD). This paper researches to which degree PD practices in a Scandinavian design and manufacturing company comply with Lean in its own context. A capability maturity tool has been developed and piloted in the case company to identify gaps and improvement potentials. The results show that the structure of the tool makes it scalable to other contexts than the case company.

Keywords: lean product development; value creation; assessment; company characteristics; improvement schemes

1. Introduction

1.1. Background

During the past decades, companies have implemented various countermeasures in response to increasingly competitive markets. Lean [1] is perhaps the most important concept that has been introduced to increase efficiency in manufacturing in modern times. However, lean production has undergone a shift from being a competitive frontier in its early days to become the present industry standard. Many companies have therefore established strategies for moving the lean concept beyond the factory floor and into Product Development (PD) [2,3]. However, PD is very different from manufacturing, and long-time discussions in the literature have yielded little progress in arriving at a unified understanding of Lean when this concept is being applied in PD. Even more importantly, there exist few documented examples of successful implementation of Lean PD, other than inside Toyota where the term *implementation* may be somewhat misleading.

Our hypothesis is that the basic nature of PD—its purpose, tasks, process, people and, last but not least, perception of value—makes the understanding and application of Lean very different from its counterparts in manufacturing. It is, therefore, a strong need in the research community to identify the characteristics of Lean PD, aiming to define a common starting point for implementation and continuous improvement as an essential part of any Lean strategy in PD.

1.2. Objective and scope

This research seeks to test a new tool developed to assess Lean capabilities at project team level. We use a hierarchical capability maturity model to investigate to which extent product manufacturing companies are engaged in Lean PD,

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and the degree to which various Lean capabilities are implemented [4, 5]. The framework can be used as a means for gathering data about factors that influence Lean PD maturity levels to sustain competitiveness. We seek to build a basis towards a more contextual implementation of Lean in PD environments, than the one(s) associated with Toyota Lean. Aiming to use the framework for data collection in our research, an audit process has been designed using an interactive workshop with cross-functional PD teams.

A case study was conducted in a Scandinavian product design and manufacturing company with its R&D hub located in Norway. The assessment framework was used to identify contextual drivers and improvement scenarios related to Lean. The industry goal was to identify strategies for Lean transformation and continuous improvement, ones that support a more contextual implementation of Lean in PD.

The assessment tool is based on an explanatory Lean PD model consisting of six components: *Understanding of customer value*; *Knowledge transformation; Standardization*; *Stabilization*; *Continuous improvement*; and *Lean culture*, [4,5]. These components, their interfaces and interrelationships make up a system, which is believed essential to value creation in the value streams of any product-oriented manufacturing company. Hence, this system represents a basic premise for competitiveness in the short-term perspective. Without organizational learning, however, a competitive value chain alone is no guarantee that a company sustain competitive as markets, competitors and technology change. Thus the PD system must be structured to enable *strategic value creation* in terms of the knowledge flow and learning across multiple projects.

The assessment model is made scalable to different business contexts, using a three-level hierarchical structure, consisting of 22 underlying characteristics and 66 capabilities at the lower level. These capabilities are linked to a descriptive text that is anchored to a capability scale. Overall, they make up a capability maturity model for assessing leanness on project team level. The structure adopted is a traditional continuous grid method with origin from Quality Management [6] where all practices are scored to a different level, [7]. The developed framework was used as an interactive research tool to elicit knowledge about Lean PD practices in the case company. Two overall questions prevail:

1) How does the PD team rate their Lean capability maturity on an explanatory ordinal scale relative to the levels deemed necessary to sustain competitiveness?
2) How does context relate to the identified Lean PD capability maturity gaps?

To answer these questions, a semi-quantitative research study was designed and piloted in a Scandinavian design and manufacturing company. We use the explanatory Lean PD model and the derivative assessment tool as a research framework. As a starting point, we presume that capability gaps are mainly driven by (intra and inter) contextual factors influencing the operational practices in PD.

Although the Lean principles may have some universal applicability [8], a principle has limited value unless it is filled with actionable content. Therefore, the overall motivation for our research is to make a contribution towards more context-driven Lean PD implementation strategies. We presume that the capabilities for creating value are strongly dependent on *both* the microenvironment of the PD team and the business context of the firm.

The reminder of this article is organized as follows: Part 2 discussed the most fundamental part of any Lean strategy: understanding of value (and waste). Part 3 presents the fundament and the implementation strategy for the case study. The results from piloting the assessment tool in a Scandinavian design and manufacturing company is summarized in Part 4, and conclusions and further work are given in Part 5.

2. Understanding value in the context of PD

2.1. Identifying waste

The single most important factor in Lean is the understanding of value. In Lean production, value is said to be created if a specific operation or process step meets *all* three of the following requirements [9]: (a) The customer is willing to pay for (the result that leads from) the activity; (b) It transforms the physical shape of the object or product; and (c) It is done correctly first time. On the contrary, *waste* occurs when an operation fails to meet just one of these criteria. Waste is usually divided into two categories: Type 1 waste (‘enabling activities’) and Type 2 waste (‘pure waste’). Type 1 activities do not create direct value but are still necessary to support value creation, typically administration, management, mandatory testing, etc. Pure waste in production is commonly divided into seven (or eight) subcategories, including defects, over-production, transportation, waiting, inventory, motion and processing (and underutilization of people).

Depending on manufacturing process, its efficiency may be as high as 80–90 %. In product development, however, research indicate that the overall value-added time is less than 30 % in most companies [11,12]. The high waste (or better: *lack of value*) levels in PD (>70 %) are claimed to be mainly due to Type 1. To improve leanness in PD, therefore, companies should to a larger degree replace enabling activities with value-added time. On the contrary, hunting pure waste (Type 2) is a less viable strategy due to the nature of the activities and the typical characteristics of people involved. Unlike manufacturing, waste in PD is usually not a result of doing unnecessary activities but due to shortcomings in information flow and communication. Although each PD activity may be tangible in itself, in absence of a physical work-product, the quality and flow of information is mostly intangible. This makes it difficult to detect waste in due time through ‘quality control’ and complete ‘rework’ or ‘sorting’ before the ‘part’ goes to the next ‘operation’, and ultimately to the end customer. In addition, the concurrency and interrelated nature of PD activities could make a dramatic impact of any late detection or communication of wrong information in a performance perspective.

2.2. Identifying value

In a traditional production value stream perspective, the understanding of value is the most essential part of a lean

product development strategy. However, separating value from waste is by far more complicated in PD than in manufacturing since there is no physical object to which value can be assigned. PD may be characterized as a problem-solving endeavour, in which the 'product' is information translated into knowledge aimed at reducing the risk of taking a new product to market to an acceptable level. Its primary goal is thus "to make a recipe for producing a product that conforms to the requirements stemming from customer or market needs" [12]. The input, processing and use of information must be right to generate new, valuable information that increases the confidence in the 'recipe' In order to maximize value, it is thus essential to get the right information in the right place at the right time. According to [13], "all the value in product development is embodied in the *essential deliverables* needed to launch a new product".

There are multiple definitions of value in the literature, depending on the specific context. Table 1 lists a comparison of different definitions of value identified in the literature. To the very basic, customer value may be defined as "the difference between what a customer gets from a product, and what she has to give in order to get it". Value starts with the final customer and her perception of value based on her needs, wants, meanings and experiences associated with the product. Value is then 'pulled up' the chain of successive external (e.g. corporate buyers) and internal customers (e.g. manufacturing). Customer benefits associated with a product are related to numerous complex, multi-dimensional characteristics (features, attributes, properties), as well as meanings and experiences of a product in everyday life [13] representing the most difficult and precompetitive part of the customer value definition. These may be broken down into two different categories, including:

- *Product-related characteristics* such as requirements, features, attributes, performance, functions, capacity, dimensions and size, quality, finish, durability, strength, stiffness, power, weight, etc.
- *User-related characteristics* such as second-hand value, cost of ownership, scarcity (availability), and more emotional ones including (self-)esteem, design, style, fashion, as well as the meaning of the product and its use in the context of the user's life and environment.

Pulling customer value up the value chain generates an accumulation of needs from each intermediate individual customer. Transferring these effectively into value creating activities is an extremely challenging task. Moreover, extending the value notions to business concerns, such as project selection and portfolio management [15] makes the challenge even more complex; that is, selecting the right portfolio of projects where the company's capabilities (technology, skills and market) have the best chance to maximize customer value—within the constraints of value to other stakeholders, such as owners, employees and the society. Many companies tend to select projects with the highest estimated return on investment, e.g. net present value, rather than assessing their own overall abilities to create customer value. This strategy is in great contradiction to Lean thinking, where the understanding of what brings value to the customer is what creates financial return (value to stakeholders) in the final end—and not the other way around.

Table 1. Different definitions of value found in the literature. Several are reproduced from Chase [16]*, see below.

Source	Value definition or Quote
Miles, 1961:	"Value is the appropriate performance and cost."
Kaufman, 1985:	"Value is function divided by cost."
Shillito & DeMarle, 1992:	"Value is the potential energy function representing the desire between people and products."
Womack & Jones, 1996:	"Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer."
Slack, 1998:	"Value is a measurement of the worth of a specific product or service by a customer and is a function of: (1) Product's usefulness in satisfying customer need (2) Relative importance of the need being satisfied (3) Availability of the product relative to when it is needed (4) Cost of ownership to the customer"
Lean Aerospace Initiative, 1998:	"Value is anything that directly contributes to the 'form, fit, or function' of the build-to package or the buy-to package: • Form: Information must be in concrete format, explicitly stored • Fit: Information must be (seamlessly) useful to downstream processes • Function: Information must satisfy end-user and downstream process needs with an acceptable probability of working (risk)"
Browning, 1998:	"Value is balancing performance, cost, and schedule appropriately through planning and control."
Deyst, 2001:	Value is the amount by which risk is reduced per resource expended.
Stanke, 2001:	"Value is a system introduced at the right time and right price which delivers best value in mission effectiveness, performance, affordability and sustainability and retains these advantages throughout its life."
Other sites [16]:	"Value is anything that enhances performance (form, fit, & function) as measured by cost, schedule, and risk from the perspective of the customer, be they external and internal." "Value is a balance between performance, schedule, and cost." "Value is a product design and manufacturing plan that enable the building and delivery to the customer of a product that meets the form, fit, and function requirements that the customer wants." "Value is the knowledge that adds form, fit, or function to the 'design-to' package." "Value happens when all of the stakeholders agree." "Value is in the eye of the beholder. It must be tied to who is making that judgment and what the alternative is."
Mascetelli [13]	"Any activity or task that transforms a new product design (or the essential deliverables needed to produce it) in such a way that the customer is both aware of it and willing to pay for it".
Reinertsen [18], and private communication:	"A development activity is value-added if the customer is willing to pay more for the product [design] after the activity is completed than before due to the risk(s) mitigated through the activity itself."
Mascitelli [17] and private communication:	"A development activity is value-added if it transforms a new product design (or the essential deliverables needed to commercialize it) such that *the product's profit margin and/or market share are positively impacted*."

*J.P. Chase, 'Value creation in the product development process', Master of Science in Aeronautics and Astronautics, MIT, 2001.

Continuous improvement is an important part of any Lean strategy, this being manufacturing or PD. Any change or improvement effort assumes knowing the current condition, indicators and the path forward to arrive at a more desirable future state. Thus, it is essential be able to measure the effectiveness of a PD process by addressing *value added* of the activity at each step of the process. Value-based performance indicators should serve as guidance to resource allocation, process measurement and process improvement.

In the reminder of this paper, the value notion will be been taken further into the development of a practical tool for assessing leanness in areas important to any PD organization's ability to create value in its day-to-day operations. The goal is to test a tool developed for identifying areas as a starting point for continuous improvement and Lean transformation in PD. The output from the assessment process is a list of prioritized improvement areas based on a Lean, value-based, capability maturity approach.

3. Case study

3.1. Structure of assessment tool

As a first step in developing the assessment tool, existing Lean PD models in the literature were identified, synthesized, analyzed and converted into a six-component LeanPD model: (1) Customer value; (2) Standardization; (3); Stabilization; (4) Knowledge and Learning; (5) Lean Culture; and (6) Continuous Improvement. Each component was divided into sets of characteristics, describing its key attributes. Each of the characteristics was decomposed further into subsets of three practices (sub-characteristics or capabilities), which collectively represent the key attributes of each individual characteristic. Each capability was given by situational descriptions of process, practice or behavior for different Lean maturity levels, allowing the auditee to assess the company's PD practice. To reduce complexity and detail level, descriptive statements for three different maturity levels—low (1), intermediate (3) and high (5)—were codified and linked to a Likert-scale. The respondents were asked to interpolated between low and intermediate (2) and intermediate and high (4) in case the specific practice appeared to be between one of the three levels described. The same methodology was used for both the assessment of current and desired Lean PD capability maturity levels.

It should be noted that the aim of the assessment framework is to identify Lean PD capability *gaps*—rather than scoring absolute maturity levels for each practice. The identified capability gaps are thus intended to define Lean transformation initiatives, although there may be reasons why a large gap is less interesting from a company business standpoint; e.g., if the gap is not a constraining factor (bottleneck) for PD outcomes, or it will take too much efforts or resources to close the gap, or potential countermeasures are not in support of the strategic direction of the company.

Each of the six components of the Lean PD model was divided into from two to five characteristics. A total of 22 characteristics and 66 capabilities were developed to cover the entire domain of the Lean PD model. In addition, a front sheet was made to capture quantitative information related to the individual respondent, the company, as well as organizational structure and performances.

3.2. Assessment preparation and company demographics

The case study was done as a part of an ongoing manufacturing research project. First, a documentation of the Lean PD model and fundamentals was made to create awareness prior to the assessment. A staged approach was adopted, starting with a Lean PD *awareness event*, which was directed primarily towards management. This event gave the research team valuable information about specific challenges that that the company was facing as input to the assessment.

The company selected for the case study was a Scandinavian design and manufacturing company. The Norwegian branch, which was assessed, was established in 1961 and has about 250 employees, of which about 25 are in R&D. The annual sale is about 100 MUSD (2014) for the Norwegian part of the business. The firm operates mostly in the B2B segment with corporate buyers in public sector and private companies as the main customers. However, the company maintains a close link to users of the product due to its focus on design and sustainable, ergonomic and quality products. The company has a portfolio of well-positioned products with a solid strategic fundament. It supplies three brands, in which differentiation is mainly based on ergonomics and visual design. The case company is among the 10 % most profitable companies in the industry segment.

The company operates in the high-end segment of the market for its type of products. Manufacturing is an important element of the company's strategy for producing competitive products since its production facilities and cost base are in Scandinavia. The product complexity may be classified as medium (multi-material, mechanisms, mechanical) and the development lead time is typically 3–4 years for a new product introduction. The production volume is in the medium range, typically 5-20,000 p.a. The company has Scandinavian ownership with the Norwegian unit being the global PD/R&D hub. The organization is a typical matrix structure. The PD operational modus may be classified as a balance between being project-driven and process-driven with repetitive tasks. The lean awareness level of the organization may be characterized as medium, as the company is familiar with lean manufacturing in their production operations. Also, the project group has a well thought-through approach to many of the fundamental principles associated with lean PD.

The awareness event indicated that the company is facing several challenges within PD. One of the main issues is to increase productivity in R&D, e.g., by leveraging standardization. The PD organization is also evaluating to establish a best-practice guide for preferred design and production solutions as a part of its standardization efforts. Another issue is to improve the quality of project implementation, particularly streamlining first-time product implementations, to the same level as upgrades and incremental innovations. In this connection, the company evaluates to employ visualization tools in projects. Another countermeasure is improving practices for project feedback and experience sharing at an early stage of projects—not just

lessons learned or *project post mortems*—to strengthen the knowledge value stream. The company seeks to become more aware of "who the customer is", including differences between decision-makers, customers and users. They also aim to improve the understanding of customer needs, wants (spoken and unspoken) through surveys and field observations. In this connection, they are also evaluating capabilities for getting the "right ideas" into the PD funnel—one question that was raised was if the company is currently too fact-based in their project prioritization? The company is also in the process of evaluating if the size of the PD group allows full focus on establishing a system seeing knowledge as a separate value stream. A final issue that the company is facing is streamlining its purchasing and distribution network.

3.3. Implementation and execution

The research team included a chief researcher who managed and facilitated the assessment, and two researchers, who made the research protocol and data analyses. The assessment was conducted as a two half-day workshop with six people from different functional areas of the company, including design, engineering, manufacturing, functional manager(s) and head of R&D. The assessment event lasted for 7 hours in total.

The introductory part included a discussion into the true meanings of Lean in the context of the firm's PD operations. As a next step the audit team completed the questionnaire on individual basis. In several cases, the auditees needed guidance and additional information from the research team to complete the assessment sheet. The scoring of each individual auditee was then collected and processed into a format suitable for further discussion and evaluation. It happened occasionally that the ratings were significantly different between individuals. For example, manufacturing people typically scored engineering capabilities different than did engineers. In case the difference was significant, this initiated a discussion within the audit team to clarify potential misconceptions and thus arrive at a more uniform rating.

4. Results

As discussed above, understanding of value is the most fundamental principle of Lean PD. Therefore, the first part of the assessment tool requested the auditee to estimate her own time spent on value-adding activities, based on a specific definition of value in PD with inspiration from Table 1. The results indicated that the average value-adding time was around 33%, varying between 25 % and 40 %. Although not statistically significant, these numbers are around 10–15 % higher than claimed numbers from US companies [10].

Resource utilization and efficiency are key factors for PD and performance, and hence business success. Here the responses indicated that close to 100 % (varying between 80 and 120 %) of the hours were booked in advance of a work week for the team as a whole. In other words, no time was in practice planned to solve unforeseen problems, representing perhaps the most fundamental facet of PD. This does not reflect a PD environment for event-driven PD [17] and systematic learning through agile learning cycles.

		Charateristic	Current	Goal	Gap
Customer focus	Role and Values	1,1	1	3	3	0
	Interface between customer and design engineer	1,2	2	3	5	2
Culture	Trust, Respect and Responsibility	2,1	3	3	4,5	1,5
	Fact Based Decision Making	2,2	4	4	4,5	0,5
	Creativity and Entrepeneurship	2,3	5	3	5	2
	Digital Tools	2,4	6	2	4	2
	Simple and Visual Communication	2,5	7	2,5	4	1,5
Stabilize	Resource planning and Management	3,1	8	3	5	2
	Product and Portfolio Management	3,2	9	4,5	5	0,5
	Communication and Information Flow between org levels	3,3	10	3	4	1
	Manufacturing Role in Product Development	3,4	11	3	4	1
	Supplier Role in Product Development	3,5	12	2,5	4	1,5
Standardize	Standardization of the Product Development Process	4,1	13	4	4	0
	Standardization for Flexibility	4,2	14	3	4	1
	Standardization in Design Strategy	4,3	15	3	4,5	1,5
	Standardization of Problem Solving	4,4	16	3	4	1
Knowledge	Value stream	5,1	17	2,5	4,5	2
	Ownership and management	5,2	18	2	4	2
	Cross functional knowledge flow	5,3	19	2	4,5	2,5
	Set based concurrent engineering	5,4	20	3,5	4,5	1
Continuos improvements	Continuos Improvement in Product Development	6,1	21	3	4	1
	Productivity Measurement in Product Development	6,2	22	4	4	0

Fig. 1. Assessment results for the 22 characteristics.

Multitasking is a constraining factor regarding efficiency, particularly in PD where focus is essential and the 'tool set-up time' is synonymous with the human brain's ability to switch focus from one problem to another. The team members claimed to work on 4.0 projects in average, varying between 2 and 6 projects depending on function. The auditees were also requested to provide historical data related to PD project performance in terms of meeting initial goals related to product performance (81 %), lead time (64%), NPD cost (76%) and product cost (83 %).

Fig. 1 shows the assessment results for current and desired Lean PD capability maturity ratings averaged and rounded off to the closest 0.5 due to sample size. The nomenclature (*i*,*j*) refers to characteristic *j* for main component *i*. The most significant capability maturity gaps are associated with component *Knowledge transformation* with gaps 2 or higher for three out of four characteristics. In other words, the auditee team claims that the company has a significant improvement potential in terms of (5,1) Leveraging the role of knowledge as a means to capture new markets and grow the business, (5,2) Defining knowledge ownership and managing the knowledge transformation process, and (5,3) Improving practices for transferring knowledge between functional departments. The company also has a potential in employing set-based concurrent engineering as a means for problem solving (5,4), knowledge generation and learning—although to less degree than for the three other characteristics within component *Knowledge transformation*.

The assessment also revealed gaps of 2.0 within component *Culture*, including capabilities (2,3) Creativity and entrepreneurship and (2,4) The role of digital tools. In other words, the significant capability gaps associated with the former indicate potential for improving the way the company encourages and values creativity among individuals, and leverage this as a part of its product and technology strategy. Gaps within (2,4) indicate that the company may have to rethink and redefine the perceived role digital tools play in achieving business and PD goals. In Lean, this means that the company must place people and process over tools and technology. Moreover, stabilization of the PD process has to take place before introducing any automation such as digital tools; the opposite may make the process *less* efficient. Note also that digital tools are for the most commercially available and can in principle be available to any company. Therefore,

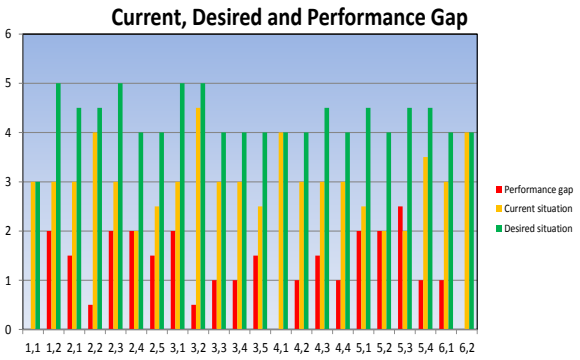

Fig. 2 Capability gaps, current and desired situation for 22 characteristics.

a digital tool does not by itself offer any competitive advantage; what does, on the other hand, is the way the tool is integrated and implemented to meet the needs of people and processes.

Only one characteristic within component *Stabilization* demonstrated a Lean PD capability gap of 2.0; namely, (3,1) Resource planning and management. This implies a potential in improving practices to ensure that projects and functional departments get the resources they need, when needed. In the assessment tool, this characteristic includes three capabilities: (3,1,a) Providing a *Hoshin*-system for resource management; (3,1,b) Establishing operational practices for work levelling; and (3,1,c) A bottom-up system for resource allocation.

According to the assessment results, the customer plays an important role in the design and engineering process of the company. The second characteristic within *Customer value*, however, (1,2) Interface between customer and design engineering team reflects a significant gap between current and desired capabilities. In essence, relative to Lean practices, the company has a way to go to establish practices ensuring that customer desires, needs and wants effectively reach design engineers. Lean countermeasures in this respect are (1,2,a) Establishing strategies for requirement engineering; (1,2,b) Leveraging need finding and customer integration in PD, and (1,2,c) Proactively establishing effective customer feedback loops, other than quality (problem) loops.

Fig. 2 illustrates graphically the collective scores from the assessment. The company used the results from the assessment to prioritize continuous improvement efforts based on identified capability gaps, resources, to which degree the capability constrains the output, and finally the strategic direction.

5. Conclusions and further work

We propose a Lean PD model consisting of six main components. The model is based on a review of more than 100 publications over the past 25 years. It is decomposed into 66 capabilities to which Lean PD maturity can be assessed based on situational descriptions using a maturity grid method tied to an ordinal scale.

A pilot study was conducted to test the viability of the tool in real-world use. The test bed was a Scandinavian product manufacturing company, involving a cross-functional audit team. The implementation has been useful in mapping out a process for assessing Lean PD capabilities with the goal of arriving at committed improvement initiatives. The case company identified the most significant capability gaps associated with their Knowledge transformation practices, followed by different capabilities within Stabilization, Customer value and Culture. The selected assessment strategy of focusing on gaps, rather than absolute score levels, allowed for a more quantitative comparison between characteristics, hence reducing the drawback of using an ordinal scale approach. This along with the maturity grid approach, using situational descriptions of the capabilities, enabled context to be a part of the evaluation since different companies will have different needs associated with each capability.

The present study can be considered as a cross-sectional study of the current Lean PD situation within the case company. The assessment resulted in a set of Lean PD transformation initiatives within the company. We therefore suggest conducting a longitudinal study where we redo the assessment to compare the situations before and after the improvement initiatives were introduced. A fundamental question is if the introduction of Lean practices has yielded any significant progress in the company's PD capabilities.

Once the capability of the Lean PD assessment tool is demonstrated, our plan is to use it on a broader level across companies within one industry as well as across industries. In the former, it is of particular interest to identify any significant positive correlation between (any improvement in) Lean PD capabilities and new product performance of the company. In the latter, efforts will be made to identify potential contextual factors—external and internal ones—that may have a direct or indirect impact on Lean PD gaps and levels. An example of an appropriate research question is: do project-driven organizations have a higher potential in improving their organizational learning capabilities than more functional organizations? Gaining such new insights into contextual differences between various types of companies will help identify key dimensions for categorization. This will again open up the way for developing more contextual implementation strategies for Lean PD.

References

[1] Womack, J.P., Jones, D.T., and Roos, D. The Machine that Changed the World: The Story of Lean Production, New York, Harper Perennial, 1990.
[2] Womack, J.P., Jones, D.T. Lean Thinking: Banish Waste and Create Wealth in Your Corporation, New York Freed Press, 1996
[3] Baines, T., Lightfoot, H., Williams, G.M. and Greenough, R. State-of-the-art in lean design engineering: A literature review on white collar lean, J. Engineering Manufacture, Proc. IMechE, Vol. 220, Part B, 2006, p.1539–1547.
[4] Welo, T., On the application of lean principles in Product Development: a commentary on models and practices, Int. J. Product Development, Vol. 13, No. 4, 2011.
[5] Welo T., Ringen G. Investigating Lean development practices in SE companies, 2015 Conference on Systems Engineering Research, Procedia Computer Science, Vol. 44, Elsevier, p. 234-243, 2015.
[6] Crosby, P.B. Quality is Still Free: Making Quality Certain in Uncertain Times, New York: Mc Graw-Hill, 1979.
[7] Nightingale, D.J., and Mize, J.H. Development of a lean enterprise transformation maturity model, Information Knowledge Systems Management, vol. 3, no. 1, 2002, p. 15-30.

[8] Sousa, R., Voss, C.A., Quality management: universal or context dependent?, Production and Operations Management 10 (4), 2001, p. 383–404.
[9] Fiore, C. Accelerated Product Development – Combining Lean and Six Sigma for Peak Performance, The Productivity Press, NY, USA, 2005.
[10] Kennedy, M.N., Harmon, K. and Minnock, E. Ready, Set, Dominate: Implement Toyota's Set Based Learning for Product Development, Oaklea Press, Richmond, VA, 2008.
[11] Radeka, K. The Mastery of Innovation, © 2012 K. Radeka, 2012.
[12] Reinertsen, D.G. Lean thinking isn't so simple, *Electron Des.*, Vol. 47, No. 19, 1999, p.48.
[13] Mascitelli, R. The Lean Product Development Guidbook, Technology Perspectives, Northridge, CA, 2007.
[14] Verganti, R. Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean, Harvard Business School Publishing Company, Boston, MA, USA, 2009.
[15] Cooper, R.G. Benchmarking new product performance: results of the best practices study, European Management Journal, Vol. 16, No. 1, 1998, pp.1–17.
[16] J.P. Chase, Value creation in the product development process, Master of Science in Aeronautics and Astronautics, MIT, 2001.
[17] Mascitelli, R. Mastering Lean Product Development, Technology Perspectives Inc., 2011.
[18] Reinertsen, D.G. The Principles of Product Development Flow, Celeritas Publishing, CA, 2009.